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Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 3-2000
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July 1991

Stock Assessment and Management of Pacific Herring in Prince William Sound, Alaska, 1989

by

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and

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ABSTRACT

An estimated 1,111.3 tonnes of Pacific herring *Clupea harengus pallasi* were harvested by the fall 1988 food-and-bait fishery in Prince William Sound, Alaska. The 1989 spring sac roe and spawn-on-kelp fisheries in Prince William Sound were not opened because of the oil spill resulting from the grounding of the tanker *M/V Exxon Valdez* on 24 March 1989. There were five major spawning concentrations of herring in Prince William Sound during 1989: (1) southeast-shore area; (2) northeast-shore area; (3) north-shore area; and (4) Naked Island area; and (5) Montague Island area. An estimated 35,956.3 tonnes of herring were observed spawning in these areas during aerial surveys. This compared to 52,235.5 tonnes of spawning herring estimated from the spawn deposition surveys. The spawn deposition survey estimate was 1.45 times larger than the aerial survey estimate. Herring were observed to have spawned on a total of 163.3 km of shoreline in the five areas. The herring had a estimated mean weight of 116 g. The total spawning biomass (52,235.5 tonnes) was unharvested in 1989 because all the 1989 spring herring fisheries in Prince William Sound were closed. The estimated exploitation rate for the 1988-1989 fishing season (food-and-bait fishery only) was 2.1% by weight and 2.7% by number. The biomass of herring in Prince William during the 1988-89 season was dominated by the 1984 year class (age-4 fish in the 1988 food-and-bait fishery, and age-5 fish in the total spawning biomass). The 1988 commercial food-and-bait harvest was composed of 38.7% by weight and 37.7% by number age-4 herring. The total spawning biomass in 1989 was composed of 63.6% by weight and 69.7% by number age-5 herring.

KEY WORDS: Pacific herring, *Clupea harengus pallasi*, Prince William Sound, total spawning biomass, aerial survey, spawn deposition survey, age-weight-length-sex, food-and-bait, sac roe, spawn-on-kelp, pound fishery, *M/V Exxon Valdez*, oil spill

INTRODUCTION

Pacific herring *Clupea harengus pallasi* spawn throughout Prince William Sound each year from mid April through early May. Even though the herring that spawn within Prince William Sound may be composed of several populations, they are managed as a single stock. This stock has been defined as those herring that spawn within the coastal waters between Point Whitshed and Cape Fairfield (Figure 1).

There are five commercial fisheries that harvest or use herring within Prince William Sound, Alaska, each year: (1) purse seine food-and-bait fishery; (2) purse seine sac roe fishery; (3) gill net sac roe fishery; (4) wild spawn-on-kelp fishery; and (5) pound spawn-on-kelp fishery. Since 1969 the five commercial fisheries have harvested or used 6,258.6 tonnes of herring annually (Table 1). The purse seine sac roe fishery has accounted for an average of 65.9% (4,685.2 tonnes) of the herring, followed by the wild spawn-on-kelp fishery with 28.3% (1,281.4 tonnes), the food-and-bait fishery with 14.1% (675.2 tonnes), the pound spawn-on-kelp fishery with 5.6% (488.2 tonnes), and the gill net sac roe fishery with 3.0% (239.0 tonnes).

Several different gear types, including purse seines and trawls (pair, midwater, and otter) have been used to harvest herring in the Prince William Sound food-and-bait fishery (Table 2). The majority of the herring harvested in the food-and-bait fishery have been caught in purse seines. Since 1982 purse seines have been the only gear type used in the food-and-bait fishery.

The two spawn-on-kelp fisheries have annually harvested an average of 199.3 tonnes of spawn-on-kelp product since 1969. The wild spawn-on-kelp fishery has accounted for most of the spawn-on-kelp harvest, averaging 160.2 tonnes of spawn-on-kelp product (Table 3). However, the pound spawn-on-kelp fishery, which developed from the wild spawn-on-kelp fishery in 1979 and has been increasing rapidly since 1985 (Randall et al. 1985), has had an average harvest of 39.1 tonnes of spawn-on-kelp product (Table 4).

The spawning biomass of herring in Prince William Sound has been estimated since 1978 from aerial surveys (Brady 1987). Aerial survey estimates have ranged from 8,371.5 tonnes in 1978 to 46,348.1 tonnes in 1981 (Table 5). However, the accuracy or comparability of the aerial survey estimates was suspect due to differences in observers, weather, water visibility, varying school depths, and varying spawning potential of the herring due to differences in age structure (Randall et al. 1985; Brady 1987). Because of these differences, a second independent estimate was used in 1989 to estimate the spawning biomass (Biggs and Funk 1988). Spawn deposition surveys had been used extensively for estimating the spawning biomass of herring in British Columbia and Southeast Alaska (Haegele et al. 1981; Blankenbeckler and Larson 1987).

Feasibility studies using spawn deposition survey techniques were conducted in Prince William Sound in 1983 and 1984 by Jackson and Randall (1983, 1984). They concluded that directly measuring spawn deposition was a more precise method of estimating the spawning biomass than aerial surveys (Randall et al. 1985). From the feasibility studies, the total of spawning biomass of herring was estimated at 19,958.0 tonnes in 1983 and 72,311.8 tonnes in 1984 (Table 5). In 1988 a

complete spawn deposition survey was conducted, and it provided an estimate of 53,804.9 tonnes (Biggs and Funk 1988). The spawning success of herring has also been measured indirectly since 1978 by mapping the amount of shoreline where spawning was aerially observed. This measurement, kilometers-of-spawning, has ranged from 76.3 km in 1978 up to 267.7 km in 1988 (Table 5).

Age, weight, length, and sex (AWLS) information from the harvest and spawning biomass has been collected since 1973 (McCurdy 1986; Sandone et al. 1988a). Samples were collected from each commercial harvest and test fishing conducted by the Alaska Department of Fish and Game (ADF&G). AWLS information were used to estimate: (1) the age and sex composition, mean weight-at-age, mean length-at-age; and (2) the contribution of each age class to the harvest of each commercial fishery, the escapement biomass, and the total spawning biomass of herring within Prince William Sound. This information were also used to update harvest strategies, monitor year class strengths, measure recruitment, and prepare a year-ahead forecast of abundance (Baker 1990).

In 1989 a detailed stock assessment program was conducted on the herring stock in Prince William Sound. The program consisted of monitoring the harvest from the 1988 fall food-and-bait fishery; estimating the total spawning biomass in Prince William Sound in 1989; and estimating the age, weight, length, and sex composition of herring in the commercial harvest, escapement biomass, and total spawning biomass. Normally, the stock assessment program would have also monitored the harvest of the 1989 spring sac roe and spawn-on-kelp fisheries. However, the 1989 spring fisheries were not opened in Prince William Sound because of the oil spill resulting from the grounding of the tanker *M/V Exxon Valdez* on 24 March 1989. The purpose of this report is to present the methods used and the results obtained from the stock assessment program. This report does not contain information concerning the effects of possible oil contamination on herring in Prince William Sound.

Objectives

The specific objectives of the 1989 stock assessment program were:

1) to estimate the age, sex, and size composition of the commercial harvest of each fishery, escapement biomass, and total spawning biomass of herring in Prince William Sound;

2) to measure the harvest and estimate the use of herring by the commercial fisheries in Prince William Sound;

3) to estimate the total spawning biomass of the major herring stock(s) returning inshore to spawn in Prince William Sound from both aerial surveys and spawn deposition surveys; and

4) to map the location, duration, and intensity of herring spawning along the shoreline in Prince William Sound.

In this report, the results of the 1989 herring stock assessment program were presented along with an overview of the management of the herring fisheries in Prince William Sound.

Herring Fisheries Management in Prince William Sound

The herring stock in Prince William Sound is managed on a sustained yield basis by following guideline harvest levels set forth by the Alaska Board of Fisheries in 1988 in accordance with the Prince William Sound Herring Management Plan (ADF&G 1989). The spawning biomass is projected from the previous year's escapement as estimated from the spawn deposition and aerial survey program, adjusting for growth, mortality and recruitment (Brannian 1989). Guideline harvest levels allow for a sliding-scale exploitation rate ranging from 0% to 20% of the projected spawning biomass. Commercial fishing is not allowed if the estimated spawning biomass is less than the threshold level of 7,620.0 tonnes. If the projected spawning biomass is between 7,620.0 and 38,556.0 tonnes, the level of harvest is set between 0.0% and 20.0% and is based upon the Department's assessment of the status of the herring stock. If the projected spawning biomass is 38,556.0 tonnes or greater, then the exploitation rate is set at the maximum of 20%. The guideline harvest of herring is allocated to each fishery as follows: 16.3% to the food-and-bait fishery; 8.0% to the wild spawn-on-kelp fishery; 14.2% to the pound spawn-on-kelp fishery; 58.1% to the purse seine sac roe fishery; and 3.4% to the gill net sac roe fishery (ADF&G 1989). Harvest quotas for the spawn-on-kelp fisheries are also set using the following relationships: 1.0 tonne of wild spawn-on-kelp may be taken for every 8.0 tonnes of herring allocated to wild spawn-on-kelp fishery; and 1.0 tonne of spawn-on-kelp in pounds may be taken for every 12.5 tonnes of herring allocated to the pound spawn-on-kelp fishery (ADF&G 1989).

The food-and-bait purse fishery is the first fishery to occur in the management year, 1 July - 30 June. The food-and-bait fishery opens by regulation 1 September and may extend through 31 January. However, the fishery is closed by emergency order authority if the guideline harvest level is attained prior to 31 January. Even though the primary gear for the food-and-bait fishery are purse seines, the legal gear for this fishery includes purse seines, gill nets, and trawls (ADF&G 1988).

The pound spawn-on-kelp fishery occurs during April and May. Purse seines are used to collect mature herring that have not yet spawned. The captured herring are transferred from the purse seine into a net pen through the use of net doors. After the web of the door of the purse seine and the net pen have been laced together, the volume of water enclosed in the purse seine is reduced. This forces the herring to swim into the net pen, after which the web door of the net pen is raised and closed. The net pen is then towed to the pound site where the herring are transferred into the pound in a similar fashion. However, before the transfer of herring into a pound occurs, fronds of imported *Macrocystis* are suspended vertically from lines secured on the sides of the pounds. The kelp fronds serve as the spawning substrate for the adhesive herring eggs. The herring are confined in the pound until spawning activity is completed. The herring are then released and the resulting spawn-on-kelp product is harvested. The pound webbing also

receives herring spawn and must remain in the water until the herring embryos have hatched. Although the adult herring are released after spawning, mortality is thought to be high due to stress, tissue damage, and scale loss which occurs during the confinement period. For management purposes, mortality of the pounded herring is assumed to be 100.0%. Participation in the pound fishery is governed by the Commercial Fisheries Entry Commission (CFEC).

The wild spawn-on-kelp fishery usually occurs in late April or early May. The spawn-on-kelp product is harvested by diving and cutting the frond 10.2 cm above the stem of the kelp. The location of the wild spawn-on-kelp fishery is determined from aerial surveys. The locations with the longest duration and intensity of spawning are the areas that will be opened for harvesting spawn-on-kelp product. The wild spawn-on-kelp fishery has a fixed guideline harvest allocation. The herring used in this fishery is estimated based upon the assumption that the mean roe recovery is 10.0% with 80.0% of the spawn-on-kelp product consisting of roe (eggs).

The purse seine and gill net sac roe fisheries usually occur during the later half of April. The timing of the sac roe fisheries is established to coincide with peak roe recovery which will maximize fishery value. To prevent gear conflicts, the gill net sac roe fishery usually follows the closure of the purse seine fishery (Alaska Board of Fisheries 1986). Participation in both sac roe fisheries is governed by the CFEC.

For 1989 the projected total spawning biomass of herring in Prince William Sound was 49,803.6 tonnes, and the total harvest allocation, based on a 20.0% exploitation rate, was 9,960.9 tonnes (Brannian 1989). Following the management plan, the guideline harvest of herring by fishery was 1,623.9 tonnes to the 1988 food-and-bait fishery, 796.5 tonnes to the wild spawn-on-kelp fishery (converts to 99.6 tonnes of spawn-on-kelp product), 1,414.3 tonnes to the pound spawn-on-kelp fishery resulting in 113.2 tonnes of spawn-on-kelp product; 5,787.3 tonnes to the purse seine sac roe fishery; and 338.7 tonnes to the gill net sac roe fishery.

METHODS

Harvest Information and Estimates

Information on the amount of herring harvested in the 1988 food-and-bait fishery was obtained from harvest receipts (fish tickets) which document each sale by a licensed fisherman. The harvest receipts were totaled at the end of the fishery to provide the total harvest for the fishery.

Age, Weight, Length, and Sex Statistics

Data Collection

Age, weight, length, and sex (AWLS) information were randomly collected from the 1988 fall commercial food-and-bait fishery and from the major sightings of spawning herring throughout Prince William Sound. Samples were obtained during the food-and-bait fishery from fishing vessels that were randomly selected from throughout the management area. Ideally, during each fishing period, samples from the harvest of a minimum of five vessel were collected. Purse seine vessels brought their harvests into the processors in Cordova; samples were dip-netted from the hold of the boats or were collected from the processor as they were pumped into the processing plant. Samples were collected from the major sightings of spawning herring by vessels chartered by the department. Purse seines were used to collect herring from the major sightings of spawning biomass. Samples were dip-netted from the seine net catches.

All samples collected during the spawning migration were placed in polyethylene bags and clearly labeled. The samples were picked up daily, or as weather permitted, by the aerial survey plane or by a chartered float plane. All samples were delivered to the department's laboratory in Cordova, placed in fish totes, chilled with ice, and logged in a sampling notebook.

In the lab, herring were randomly sampled from the fish totes. Ten herring were placed on a sampling tray at one time. From each herring sampled, the weight was measured to the nearest 0.01 g using an electronic scale, the standard length (tip of snout to the end of the hyperal plate) was measured to the nearest millimeter using calipers, sex was determined from inspection of the gonads, and one readable scale was removed from the preferred area (i.e., the area between the left pectoral fin and the lateral line approximately 3-4 scales posterior to the fin origin).

Each scale was cleaned and checked for regeneration. If the scale was regenerated or unreadable, the process was repeated until one readable scale was found for each fish sampled. The individual scales from the ten fish were mounted on a labeled glass slide (25 x 75 x 1 mm) by dipping the readable scale into mucilage glue solution (1:10 solution of mucilage glue and water) and placing on the glass slide. Labels for the glass slides included year, fishery, location, sample number, gear type, dates, and slide number. Each scale was pressed firmly against the slide with a paper towel after mounting to remove excess glue. After all ten scales had been mounted on a slide, a second glass slide was placed on top of the first and the two slides were taped together with cellophane tape. The completed scale mounts were stored in a slide box for subsequent age estimation and permanent storage.

Age of each herring sampled was estimated from the mounted scales by a committee of two to three persons. Scale images were projected on a microfiche reader (50 x) and each person estimated the age from each scale independently. If there were differences between the estimated age, then the differences were discussed and the age was estimated by mutual consensus.

Annulus formulation is assumed to take place in the spring of the year prior to spawning. Therefore, all herring captured in the 1988 food-and-bait fishery were from 5 to 10 months older than the herring captured in the spring spawning migration in 1989. Because of this, herring from the food-and-bait fishery were from a year class 1 year older than the fish sampled in the 1989 spring spawning migration. For example, age-4 herring in the 1988 food-and-bait fishery were from the 1987 year class, and age-4 herring from the 1989 spawning migration were from the 1985 year class. In addition, all herring sampled during the 1989 spawning migration were assumed to have an annulus on the outer edge of each scale. The herring sampled in the food-and-bait fishery were not assumed to have an annulus on the outer edge of the scale unless one was clearly visible.

Sample Sizes

Sampling for AWLS information was stratified by time, area, and fishery, and the sample sizes for each stratum was set at 560 fish for the 1988 food-and-bait fishery. This was reduced to 450 fish for the 1989 fisheries because we found that the smaller sample size would meet precision and accuracy requirements and still account for unreadable scales. The sample size allowed for simultaneous estimation of the proportions by age when sampling form a multinomial population (Thompson 1987). The goal was to select the smallest sample size for a random sample from a multinomial population such that the probability was at least $1-\alpha$ (precision) that all the estimated proportions were simultaneously within 5% (accuracy = 0.05) of the true age proportions of the population. In 1988 the sample size was based on simultaneous confidence intervals for the binomial distribution where the major age class comprised 50% of the sample. The same level of precision and accuracy was required and with 5 age groups, a sample size of 543 was increased to 560 to account for unreadable scales (D.R. Bernard, Alaska Department of Fish and Game, Anchorage, personal communication). In 1989 the smallest sample size was again designed for a random sample from a multinomial population such that the probability was 90% that all the estimated proportions were simultaneously within 5% of the true age proportions of the population. It was shown that 403 fish would guarantee this level of precision and accuracy for any number of age classes and proportions (Thompson 1987). The number of fish was increased to 450 to account for unreadable scales.

We also examined temporal (time) and spatial (area) differences in the AWLS composition of herring in Prince William Sound. Samples collected from the same location on successive days or from adjacent locations on the same day were tested for differences in age compositions between samples with a chi-square test. Subsamples of approximately 300 herring were sampled from each strata. If the age compositions of the herring in the subsamples were not significantly different ($\alpha > 0.05$), then the subsamples were pooled into one sample. However, if the age compositions were significantly different ($\alpha > 0.05$), then sampling continued until enough samples were collected from each stratum.

Data Analysis

The age composition (P_a) by sex was estimated for each time-fishery stratum as follows:

$$P_a = \frac{n_a}{n} * 100, \qquad (1)$$

where,

n_a = number of male or female herring in the sample that were age a, and
n = total number of herring in the sample.

The sex composition of herring for each time-fishery stratum was estimated by dividing the number of male or female fish in a sample by the total number of fish in a sample and by multiplying times 100.

The mean weight-at-age ($\bar{W}_a$) for herring was estimated for each time-fishery stratum as follows:

$$\bar{W}_a = \frac{\sum_{i=1}^{n_a} W_{ai}}{n_a}, \qquad (2)$$

where,

W_a = individual weight of i herring that were age a, and
n_a = number of herring in the sample that were age a.

The variance for the sample weight-at-age, $Var[W_a]$, was estimated by:

$$Var[W_a] = \frac{\sum_{i=1}^{n_a} (W_{ai} - \bar{W}_a)^2}{n_a - 1}. \qquad (3)$$

The standard deviation of the sample weight-at-age was estimated by taking the square root of equation (3).

The mean length-at-age, variance, and standard deviation of the sample length-at-age measurements were calculated by substituting the individual length of each herring (L_{ai}) for W_{ai} in equations (2) and (3).

The contribution of each age class by weight to the harvest of each commercial fishery, escapement biomass, and total spawning biomass in each major spawning area was estimated by:

$$B_a = \frac{n_a \bar{w}_a}{\sum_{a=1}^{max\,a} (n_a \bar{w}_a)} B, \qquad (4)$$

where,

B_a = biomass of herring that was age a in the harvest of each commercial fishery, escapement biomass, or total spawning bi omass in each major spawning area;

B = total biomass of herring in the harvest of each commercial fishery, escapement biomass, or total spawning biomass in ea ch major spawning area.

The contribution of each age class by number to the harvest of each commercial fishery, escapement biomass, and total spawning biomass for each major spawning area was estimated by:

$$N_a = \frac{B_a}{\bar{w}_a}. \qquad (5)$$

The contribution of each age class to the herring harvested by the commercial food-and-bait fishery was estimated based upon the age composition and mean weight-at-age of herring sampled during the harvest. The contribution of each age class to the escapement and total spawning biomass (by weight and number), mean weight-at-age, and mean length-at-age was estimated for herring in each of the major spawning areas from: (1) estimates of spawning biomass (spawn deposition surveys); and (2) pooled samples of age, weight, and length data collected from herring captured by non-selective gear (purse seines) within each major spawning area.

The contribution of each age class (by weight and number) to the escapement and total spawning biomass was estimated by adding the estimated spawning biomass from the major spawning areas. The mean weight at age for the spawning biomass was estimated by dividing the weight of each age class by the number of fish in each age class. Mean length-at-age was not estimated for the escapement or the total spawning biomass.

The exploitation rate (by weight) was estimated for each age class of herring by dividing the weight of the total harvest by the weight of the total biomass. The exploitation rate (by number) was also estimated for each age class by dividing the number herring in the total harvest by the total number of herring in Prince William Sound for the 1988-89 season.

Aerial Surveys

Aerial Survey Methods

A total of 22 aerial surveys were flown between 30 March and 25 April 1989. Daily surveys were flown during the majority of the herring spawning migration. Aerial surveys were not flown on only 2 d because of adverse weather conditions. Aerial surveys were usually flown from a float-equipped Cessna 185. Survey coverage of Prince William Sound normally included the mainland shoreline from St. Mathews Bay to Eaglek, the Naked Island group, Green Island, and the northeastern portion of Montague Island (Figure 2). Area of coverage was varied to focus on locations were spawning activity was concentrated. A typical survey covered up to 805 km of coastline and was normally terminated by fuel capacity of the aircraft, or approximately 5 h of flying. Tide stage was not critical, but in general, more herring were visible on a rising tide.

Biomass estimates were made by converting surface area estimates to biomass. Schools of herring were classified into three different categories depending on estimated surface diameter. A *small* school was 15.25 m (50 ft) in diameter and corresponded to 9.1 tonnes of herring, a *medium* school was 30.5 m (100 ft) in diameter and corresponded to 36.3 tonnes of herring, and a *large* school was 61.0 m (200 ft) in diameter and corresponded to 145.1 tonnes of herring. A tally counter was used to enumerate the total number of *small*, *medium*, and *large* schools. The totals were recorded on standardized data forms.

To standardize the observers estimates of distance on the surface of the water, surveys were flown at a standard altitude of 457.2 m (1500 ft). This occasionally was modified because of low clouds or other reasons. A sighting tube was used to calibrate the observer to standard surface distances at a specified survey altitude and viewing angle.

Spawning Biomass Estimation

The annual peak biomass was estimated from aerial survey data as the sum of the peak biomass estimates recorded for all survey areas in Prince William Sound where herring were observed. The only exception was if two separate biomasses of herring spawned in the same area and were clearly temporally distinct. In this instance two peak estimates from the same area would be included in the annual peak biomass estimate. An example of this would be if a large biomass of herring spawned in Fairmont Bay, then no herring were seen for 4 or 5 d, and another large biomass of herring was observed spawning in Fairmont Bay. In this type of scenario, the peak estimate for each biomass would be included in the annual peak biomass estimate. In the past, only the largest of the two biomass estimates would have been included in the annual peak biomass estimate.

Kilometers of Spawning

Areas of herring spawning activity, as indicated by white milt in the water, were also documented on each survey. A set of detailed maps was carried by the

observer. When spawning was observed it was carefully charted on the appropriate map to the nearest 0.16 kilometers (0.1 miles). The annual kilometers of spawning was estimated from the aerial survey data as the sum of the kilometers of shoreline where milt was observed and charted. No adjustment was made for the intensity of observed spawning. A 1.0-km section of beach that receives spawn for only 1 d was given the same weight as 1.0-km section of beach that receives spawn for 2 d or more. It should be noted that the kilometers of spawning was considered an index of abundance for the herring.

Spawn Deposition Surveys

The objective of the spawn deposition surveys was to estimate the biomass of the spawning population of herring in Prince William Sound. Spawn deposition surveys were patterned after similar surveys in Southeast Alaska (Blankenbeckler 1987; Blankenbeckler and Larson 1982, 1985, 1987), and British Columbia (Schweigert et al. 1985). The total spawning biomass was estimated in each major spawning area based upon an estimate of the total number of eggs deposited on the spawning grounds in each area, incorporating estimates of mean weight, sex ratio, and fecundity of herring. Major spawning areas were identified and mapped during aerial surveys. The total spawning biomass was estimated by summing the estimates from all the major spawning areas.

Comparison of Spawning Biomass Estimates

A biomass ratio was estimated to compare the total spawning biomass estimates from the aerial surveys and spawn deposition surveys. The biomass ratio was estimated as the peak aerial survey estimate divided by the spawn deposition survey estimate. In comparing the two spawning biomass estimates, it must be remembered that the peak aerial survey estimate is an estimate of the observable biomass and can be an estimate of the total spawning biomass, or the biomass present just prior to the sac roe fisheries, whereas the spawn deposition survey estimates are estimates the spawning biomass after the completion of the sac roe and spawn-on-kelp fisheries. Therefore, the harvest of the commercial fisheries should be added to the spawn deposition survey estimate when comparing the two estimates.

RESULTS

Harvest Estimates

1988 Food-and-Bait Fishery

The Prince William Sound food-and-bait fishery usually opens on 1 September. However, because of the industry demand for a higher quality bait with higher oil content, the opening of the fishery was delayed until 1 November 1988. The

fishery was closed on 7 November 1989 by emergency order when the fishery was approaching the guideline harvest level. The majority of herring were harvested near Red Head (Figure 2). A total of 7 boats harvested 1,111.3 tonnes or 12,139.9 thousand herring during the fishery (Table 6). Age-4 herring comprised 38.7% of the harvest by weight and 37.7% by number (Table 7). The remainder of the harvest was split between age-2, age-3, age-5, and age-6 herring. The harvested herring had a mean weight of 91 g and a mean length of 181 mm. The contribution of each age class and mean weight-at-age of herring in the harvest were determined from an AWLS sample collected from the commercial harvest at Red Head on 1 November 1988 (Table 8). The sample of 536 herring was composed of 53.4% males and 46.6% females.

1989 Spring Sac Roe and Spawn-on-Kelp Fisheries

The 1989 purse seine sac roe fishery, gill net sac roe fishery, wild spawn-on-kelp fishery, and pound spawn-on-kelp fishery were not opened in Prince William Sound due to the oil spill resulting from the grounding of the tanker *M/V Exxon Valdez* on 24 March 1989.

Total Harvest

There were no spring sac roe and spawn-on-kelp fisheries in 1989. The only harvest during the 1988-89 season occurred during the 1988 food-and-bait fishery. A total of 1,111.3 tonnes of herring were harvested by the 1988 food-and-bait fishery (Tables 6, 7).

Spawning Biomass Estimates

Southeast-Shore Area

There was no estimate of spawning biomass from aerial surveys, and 40.6 tonnes were estimated from the spawn deposition surveys in the southeast-shore area (Tables 9, 10). However, it was estimated there was 5.6 km of spawning in the area (Table 9). The kilometers of spawning were first observed in the area on 7 April 1989.

Age-5 herring comprised 62.2% by weight and 65.9% by number of the herring in the area (Table 11). The herring had a mean weight of 122 g and mean length of 212 mm. The female herring had a mean weight of 132 g compared to 122 g for the males. The contribution of each age class and mean weight was estimated based upon a AWLS sample (n=528) collected from test purse catches at Two Moon Bay on 5 April 1989 (Table 12). Males composed 44.3% and females 55.7% of the sample.

Northeast-Shore Area

The total spawning biomass estimate of 7,184.4 tonnes that was estimated from spawn deposition surveys was 1.81 times larger than the 3,946.3 tonnes estimated

from aerial surveys in the northeast-shore area (Table 9). The majority of the spawning biomass was observed from aerial surveys on 12 April 1989 (Table 10). Herring spawned on an estimated 34.8 km of shoreline (Table 9). The spawning biomass in the area was dominated by age-5 herring, which comprised 79.3% by weight and 79.9% by number (Table 13). The remainder of the spawning biomass was split between age-4 (6.7% by weight) and age-6 (7.1% by weight) fish. The herring in this area had a mean weight of 111 g and mean length of 205 mm. The female herring had a mean weight of 115 g compared to 108 g for the males. The contribution of each age class and mean weight was estimated based upon an AWLS sample collected from herring captured by chartered purse seine fishing vessels at Galena Bay and Johnson Cove on 12 April 1989 (Table 14). The sample of 433 herring was composed of 53.6% males and 46.4% females.

North-Shore Area

In the north-shore area the total spawning biomass estimate of 18,161.8 tonnes of herring from the spawn deposition survey was 6.67 times larger than the aerial survey estimate of 2,721.6 tonnes (Tables 9 and 10). The majority of the spawning biomass were observed between 5 and 10 April 1989 during the aerial surveys (Table 10). Herring spawned on an estimated 49.4 km of shoreline in the area (Table 9). Age-5 herring dominated the biomass in the area, comprising 63.6%, by weight, and 69.7%, by number (Table 15). The remainder of the spawning biomass was split between age-6 (7.4% by weight), age-7 (6.0% by weight), age-8 (9.8% by weight), and age-9 (7.2% by weight) herring. The herring in this area had a mean weight of 129 g and mean length of 211 mm. The contribution of each age class and the mean weight were determined from 1,243 AWLS samples collected from test fish purse seine catches at Unakwik Inlet and Olsen Cove on 4 April 1989 and Cedar Bay 13 April 1989 (Tables 16 and 17). The herring sample (n=817) at Unakwik Inlet and Olsen Cove was composed of 64.6% age-5 fish (Table 16). Males composed 46.7% and females 53.3% of the sample. The herring had a mean weight of 134 g and mean length of 214 mm. The herring sample (n=426) at Cedar Bay was composed of 79.3% age-5 fish (Table 17). The remainder of the herring sampled were split between age-4 (5.4%), and age-6 (6.3%) fish. Males composed 57.0% of the sample and females 42.9%. The herring had a mean weight of 118 g and mean length of 206 mm.

Naked Island Area

The total spawning biomass estimate of 10,145.0 tonnes estimated from the spawn deposition surveys was 2.43 times larger than the spawning biomass of 4,340.9 tonnes estimated from the aerial surveys in the Naked Island area (Tables 9 and 10). Herring spawned on an estimated 22.1 km of shoreline in the area (Table 9). The majority of the herring were observed and spawned in the area between 6 and 12 April 1989 (Table 10). The herring spawning in the area were comprised of 76.8% by weight and 80.0% by number age-5 herring (Table 18). The herring in this area had a mean weight of 117 g and mean length of 208 mm. The contribution of each age class and mean weight was estimated based upon an AWLS sample collected from test fish purse seine catches at Outside Bay on 11 April 1989 (Table 19). The sample of 419 herring was comprised of 53.1% males and 46.9% females.

Montague Island Area

Based upon aerial survey estimates, the largest total spawning biomass of spawning herring was observed near Montague Island (Table 9). In the Montague Island area, 24,947.6 tonnes of herring were estimated from aerial surveys and 16,739.7 tonnes from the spawn deposition surveys. The spawn deposition survey estimate was 0.67 times smaller than the aerial survey estimate (Table 9). Herring spawned on an estimated 46.5 km of shoreline in the area (Table 9). Based upon the aerial surveys, the majority of the herring were observed and spawned in the area between 12 and 15 April 1989 (Tables 10). The herring spawning in the area were comprised 85.0% by weight and 84.7% by number of age-5 herring (Table 20). The herring in this area had a mean weight of 106 g and mean length of 200 mm.

The contribution of each age class and mean weight was estimated based upon AWLS samples collected from test fish purse seine catches at Rocky Bay on 13 April 1989, Zaikof Bay on 17 April 1989, and Stockdale Harbor on 18 April 1989 (Tables 21-23). The sample of 443 herring at Rocky Bay was 55.4% males and 44.6% females (Table 21). The herring at Rocky Bay had a mean weight of 108 g and mean length of 204 mm. At Zaikof Bay, 437 fish were sampled (Table 22). Males comprised 64.0% and females 36.0% of the sample. The herring at Zaikof Bay had a mean weight of 111 g and mean length of 201 mm. A total of 423 herring were sample at Stockdale Harbor (Table 23). The sample was composed of 54.6% males and 45.4% females. The fish weighed an average of 105 g; females averaged 110 g and males 101 g. The herring had a mean length of 195 mm.

All Areas Combined

The spawning biomass estimate of 52,235.4 tonnes of herring from the spawn deposition surveys was 1.45 times larger than the aerial survey estimate of 35,956.3 tonnes from the aerial surveys (Tables 9 and 10). Herring were observed to have spawned on a total of 158.4 km of shoreline in the four areas (Table 9). The peak aerial survey estimate was on 12 April 1989 (Table 10). Age-5 herring comprised 75.2% by weight and 78.4% by number of the spawning herring (Table 24). The remainder of the spawning herring were split between age-4 up to age-9 fish (not including age-5). The herring had an estimated mean weight of 116 g. The estimated spawning biomass, weight, and number was estimated by adding the total spawning biomass estimates, based upon the spawn deposition surveys, from the five areas.

Escapement Biomass, Total Spawning Biomass, and Exploitation Rate

Because there were no sac roe and spawn-on-kelp fisheries in the spring of 1989, the escapement was equal to the total spawning biomass. The total spawning biomass for all areas was estimated to be 52,235.5 tonnes, of which 448,892.9 thousand herring escaped the harvest and spawned in Prince William Sound in 1989 (Table 24). An estimated 75.2% by weight and 78.4% by number were age-5 herring. The herring in the escapement biomass had an estimated mean weight of 116 g. The

escapement biomass was the sum of the estimated total spawning biomasses from the areas surveyed for spawn deposition (Table 9).

The exploitation rate for herring in Prince William Sound during 1988-89 was 2.1% by weight and 2.7% by number (Tables 25 and 26). Of the total spawning biomass of 53,346.8 tonnes, or 448,892.9 thousand herring, estimated to be in Prince William Sound in 1988-89, 1,111.3 tonnes or 12,139.9 thousand herring were harvested by the 1988 food-and-bait fishery (Table 7). The exploitation rate for the 1989 spring sac roe fisheries was 0.0% because the fisheries were closed in 1989 due the oil spill resulting from the grounding of the tanker *M/V Exxon Valdez* on 24 March 1989.

DISCUSSION

The 1988 food-and-bait fishery was the only fishery to occur in Prince William Sound during the 1988-89 management season. The two sac roe and two spawn-on-kelp fisheries were closed because of the oil spill resulting from the grounding of the tanker *M/V Exxon Valdez* on 24 March 1989.

There were five major spawning concentrations of herring in Prince William Sound during 1989: (1) southeast-shore area; (2) northeast-shore area; (3) north-shore area; (4) Naked Island area; and (5) Montague Island area. Both aerial surveys and spawn deposition surveys were conducted to estimate the spawning biomass in the four areas. The differences between spawning biomass estimates from aerial surveys and spawn deposition surveys varied greatly between the five major spawning areas.

With the 1989 spring fisheries not being opened, the exploitation rate for the 1988-89 fisheries was estimated at 2.1% by weight and 2.7% by number. As was expected, the harvest by the food-and-bait fishery, escapement biomass, and total spawning biomass of herring in Prince William Sound during 1988-89 was dominated by the 1984 year class. Based upon weight and number, the 1984 year class comprised as little as 38.7% in the 1988 food-and-bait fishery and as high as 85% in the 1989 spawning biomass in the Montague Island area.

LITERATURE CITED

Alaska Board of Fisheries. 1986. Prince William Sound herring management plan. Alaska Board of Fisheries Policy 80-71-FB, Boards of Fish and Game, Juneau.

ADF&G (Alaska Department of Fish and Game). 1989. Commercial herring fishing regulations, 1988 edition. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

Biggs, E.D., and F. Funk. 1988. Pacific herring spawning ground surveys for Prince William Sound, 1988, with historic overview. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2C88-07, Anchorage.

Blankenbeckler, D. 1987. Pacific herring (*Clupea harengus pallasi*) research in Southeastern Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 203, Juneau.

Blankenbeckler, D., and R. Larson. 1982. Pacific herring (*Clupea harengus pallasi*) spawning ground research in Southeastern Alaska, 1978, 1979, and 1980. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 69, Juneau.

Blankenbeckler, D., and R. Larson. 1985. Pacific herring (*Clupea harengus pallasi*) research in Southeastern Alaska, 1982-1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 143, Juneau.

Blankenbeckler, D., and R. Larson. 1987. Pacific herring (*Clupea harengus pallasi*), harvest statistics, hydroacoustical surveys, age, weight, and length analysis, and spawning ground surveys for Southeastern Alaska, 1980-1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Data Report 202, Juneau.

Brady, J.A. 1985. Investigations of kelp used in closed pounding operations, Prince William Sound, 1983 and 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Data Report 85-3, Cordova.

Brady, J.A. 1987. Distribution, timing, and relative biomass indices for Pacific herring as determined by aerial surveys in Prince William Sound 1978 to 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Data Report 87-14, Anchorage.

Brady, J.A., and four co-authors. 1989. Prince William Sound annual finfish management report 1988. Alaska Department of Fish and Game, Division of Commercial Fisheries, Region 2 unpublished report, Cordova.

LITERATURE CITED (continued)

Haegele, C.W., R.D. Humphreys, and A.S. Hourston. 1981. Distribution of eggs by depth and vegetation type in Pacific herring (*Clupea harengus pallasi*) spawnings in southeastern British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 38:381-386.

Jackson, M. and R.C. Randall. 1983. Herring spawn deposition surveys, Prince William Sound, 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Data Report 83-16, Cordova.

Jackson, M. and R.C. Randall. 1984. Herring spawn deposition surveys, Prince William Sound, 1984. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Data Report 84-16, Cordova.

McCurdy, M.L. 1986. Prince William Sound herring commercial fishery age, weight, length, and sex data 1973 through 1983. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Management Area Data Report 86-3, Cordova.

Randall, R., P. Fridgen, and J. Brady. 1985. Review of the Prince William Sound Area commercial herring fisheries, 1985. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Management Area Data Report 85-09, Cordova.

Sandone, G.J., S. Sharr, and J.A. Brady. 1988. Prince William Sound Commercial harvest of Pacific herring, 1984-1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin 88-08, Juneau.

Sandone, G.J. 1988. Prince William Sound 1988 herring biomass projection. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A88-21, Anchorage.

Schweigert, J.F., C.W. Haegele, and M. Stocker. 1985. Optimizing sampling design for herring spawn surveys in the Strait of Georgia, B. C. Canadian Journal of Fisheries and Aquatic Sciences 42:1806-1814.

Thompson, S.K. 1987. Sample sizes for estimating multinomial proportions. The American Statistician 41(1):42-46.

Table 1. Harvest of herring by the commercial food-and-bait and sac roe fisheries, and the estimated use of herring in the wild and pound spawn-on-kelp fisheries in Prince William Sound, Alaska, 1969-89.

Harvest Year[d]	Herring Harvest						Herring Use				Total Estimated Harvest and Use (tonnes)
	Food-and-bait Fishery[a]		Sac Roe Fisheries				Spawn-on-Kelp Fisheries				
			Purse Seine		Gill Net		Pound Kelp[b]		Wild Kelp[c]		
	(tonnes)	%	(tonnes)	%	(tonnes)	%	(tonnes)	%	(tonnes)	%	
1969			322.7	94.4					19.2	5.6	341.9
1970	9.1	1.3							690.5	98.7	699.6
1971	18.1	0.5	834.0	22.9					2,791.6	76.6	3,643.7
1972	4.4	0.1	1,608.1	42.5					2,174.7	57.4	3,787.2
1973	7.7	0.1	6,336.1	85.0					1,111.5	14.9	7,455.3
1974			5,777.1	74.2	3.4	0.0			2,003.4	25.7	7,784.0
1975			5,517.1	62.4					3,327.9	37.6	8,845.0
1976			2,344.6	57.1					1,759.6	42.9	4,104.2
1977			2,071.0	57.8	1.5	0.0			1,513.2	42.2	3,585.7
1978	229.2	11.4	1,206.2	60.2	56.0	2.8			511.3	25.5	2,002.7
1979	1,170.2	17.6	3,754.5	56.5					1,717.1	25.9	6,641.8
1980	595.1	7.0	5,482.3	64.1	240.0	2.8	15.1	0.2	2,221.9	26.0	8,554.3
1981	1,285.0	8.8	12,492.5	85.9	212.8	1.5	109.5	0.8	444.2	3.1	14,544.0
1982	1,145.4	12.2	6,484.8	69.0	357.3	3.8	289.6	3.1	1,123.5	12.0	9,400.6
1983	801.2	16.8	2,471.4	51.7	95.6	2.0	314.5	6.6	1,100.2	23.0	4,783.0
1984	248.2	4.0	5,295.2	86.2	311.1	5.1	285.9	4.7			6,140.3
1985	926.9	11.1	6,423.1	77.1	374.9	4.5	455.5	5.5	149.9	1.8	8,330.3
1986	1,014.3	8.8	8,915.9	77.5	407.0	3.5	818.7	7.1	345.5	3.0	11,501.4
1987	1,157.8	15.4	4,519.8	60.3	483.8	6.5	694.0	9.3	640.1	8.5	7,495.4
1988	1,079.0	10.1	7,163.0	67.1	324.9	3.0	1,410.7	13.2	701.1	6.6	10,678.7
1989[e]	1,111.3	100.0									1,111.3
n	16	16	19	19	12	12	9	9	19	19	21
Mean	675.2	14.1	4,685.2	65.9	239.0	3.0	488.2	5.6	1,281.4	28.3	6,258.6
SE	125.4	5.9	705.9	3.9	47.7	0.6	143.4	1.4	212.0	6.0	823.3
Min	4.4	0.1	322.7	22.9	1.5	0.0	15.1	0.2	19.2	1.8	341.9
Max	1,285.0	100.0	12,492.5	94.4	483.8	6.5	1,410.7	13.2	3,327.9	98.7	14,544.0

[a] Gear type used included purse seine, pair trawl, mid-water trawl, and otter trawl. However, since 1982 purse seines were used exclusively.

[b] The equivalent harvest of herring used in the pound spawn-on-kelp fishery was estimated based on the assumption that 12.5 tonnes of herring was used to produce 1.0 tonne of spawn-on-kelp product.

[c] The equivalent harvest of herring used in the wild spawn-on-kelp fishery was estimated based on the assumptions that the average roe recovery was 10%, and 80% of the spawn-on-kelp harvest consisted of roe (eggs).

[d] The harvest year for the fall food-and-bait fishery actually occurred in the year prior to the harvest year listed. As an example, the food-and-bait harvest in the 1988 harvest year was actually the harvest for the 1987 food-and-bait fishery. It was recorded this way because the management year for herring was defined to occur from 1 July through 31 June of the following year.

[e] There was no harvest or use of herring by the commercial sac roe and spawn-on-kelp fisheries in Prince William Sound during 1989. All the sac roe and spawn-on-kelp fisheries were closed in 1989 because of the oil spill resulting from the grounding of the tanker M/V Exxon Valdez on 24 March 1989.

Table 2. Commercial harvest of herring by the food-and-bait fishery in Prince William Sound, Alaska, 1970-88.

Harvest Year	Purse Seine		Pair Trawl		Mid-Water Trawl		Otter Trawl		Total	
	Effort (Boats)	Harvest (tonnes)	Effort (Boats)	Harvest (tonnes)	Effort (Boats)	Harvest (tonnes)	Effort (Boats)	Harvest (tonnes)	Effort (Boat)	Harvest (tonnes)
1970	1	9.1							1	9.1
1971	2	18.1							2	18.1
1972	1	4.4							1	4.4
1973	1	7.7							1	7.7
1974										
1975										
1976										
1977[a]	2	15.4	2	131.8	1	82.0			5	229.2
1978[b]	2	177.3	2	897.0	1	93.6	1	2.3	6	1,170.2
1979[c]	1	464.0	2	131.6					3	595.6
1980[d]	3	934.8	3	350.2					6	1,285.0
1981[e]	6	1,079.1	2	66.3					8	1,145.4
1982	5	801.2							5	801.2
1983	2	248.2							2	248.2
1984	2	926.9							2	926.9
1985[f]	5	1,014.3							5	1,014.3
1986[g]	5	1,157.8							5	1,157.8
1987[h]	7	1,079.0							7	1,079.0
1988	7	1,111.3							7	1,111.3
n	16	16	5	5	2	2	1	1	16	16
Mean	3.3	502.1	2.2	315.4	1.0	87.8	1.0	2.3	4.1	675.4
SE	0.6	154.7	0.2	153.1	0.0	5.8			0.6	125.4
Min	1	4.4	2	66.3	1	82.0	1	2.3	1	4.4
Max	7	1,157.8	3	897.0	1	93.6	1	2.3	8	1,285.0

[a] Starting in 1977, food-and-bait herring season may have included two calendar years.

[b] Fishing season was opened by emergency order on 16 October 1978 and was extended on 7 January 1979. Deliveries were made through 2 March 1979.

[c] Fishing season was opened by emergency order 15 September 1979 and closed 31 December 1979. It was reopened by emergency order from 16 February 1980 and closed 28 February 1980.

[d] Fishing season was opened by regulation on 15 September 1980 and closed by emergency order on 7 November 1980.

[e] Fishing season was opened by regulation on 15 September 1981 and closed by emergency order on 30 September 1981.

[f] Fishing season was opened by regulation on 1 September 1985 and closed by emergency order on 15 February 1986.

[g] Fishing season was opened by regulation on 1 September 1986 and closed by emergency order on 24 October 1986.

[h] Fishing season was opened by regulation on 1 September 1987 in the General District. The Northern and Eastern Herring Districts opened on 23 September 1987. The fishing season was then closed by emergency order on 6 October for a 5-week period, reopened on 9 November, and closed for the duration of the 1987-88 season on 12 November 1987.

Table 3. Summary of herring wild spawn-on-kelp harvest in Prince William Sound, Alaska, 1969-89.

Year	Fishery Dates	Hours	Effort (Divers)[a]	Spawn-on-Kelp Harvest kg	Spawn-on-Kelp Harvest tonnes	Herring Used (tonnes)[b]
1969	18 May-31 May		3	2,404	2.4	19.2
1970	19 Apr- 6 Jun		29	86,319	86.3	690.5
1971	18 Apr-15 May		34	348,949	348.9	2,791.6
1972	30 Apr-20 May		397	271,838	271.8	2,174.7
1973	23 Apr-26 May		176	138,936	138.9	1,111.5
1974	22 Apr- 4 May		166	250,429	250.4	2,003.4
1975	25 Apr-10 May		437	415,990	416.0	3,327.9
1976	21 Apr- ?		357	219,947	219.9	1,759.6
1977	27 Apr-31 Dec		164	189,148	189.1	1,513.2
1978	20 Apr-30 Apr		66	63,911	63.9	511.3
1979	25 Apr- 3 May		198	214,640	214.6	1,717.1
1980	23 Apr-30 Apr	10	469	277,735	277.7	2,221.9
1981	25 Apr	12	214	55,520	55.5	444.2
1982	5 May- 8 May	73	151	140,432	140.4	1,123.5
1983	27 Apr	12	186	137,529	137.5	1,100.2
1984	Season Closed	20	225			
1985	6 May- 8 May	20	95	18,733	18.7	149.9
1986	30 Apr- 3 May	86	29	43,182	43.2	345.5
1987	15 Apr-17 Apr	44	60	80,014	80.0	640.1
1988	29 Apr-30 Apr	12	158	87,634	87.6	701.1
1989[c]	Season Closed					
n		9	20	19	19	19
Mean		32	181	160,173	160.2	1,281.4
SE		10	31	26,501	26.5	212.0
Min		10	3	2,404	2.4	19.2
Max		86	469	415,990	416.0	3,327.9

[a] Number of permits issued.

[b] The amount of herring utilized was based upon the assumptions that the reproductive capacity of the herring was removed from the population and the average herring roe recovery was 10% and 80% of the spawn-on-kelp harvest consisted of roe (eggs).

[c] The herring wild spawn-on-kelp fishery in Prince William Sound was closed in 1989 due to the oil spill resulting from the grounding of the tanker M/V Exxon Valdez on 24 March 1989.

Table 4. Summary of herring pound spawn-on-kelp harvest in Prince William Sound, Alaska, 1979-89.

Year	Fishery Dates[a]	Permits Issued[b]	Pounds Built[c]	Producing Pounds[d]	Spawn-on-Kelp Harvest[e]						Herring Use (tonnes)[f]
					Ribbon		Macrocystis		Total		
					kg	tonnes	kg	tonnes	kg	tonnes	
1979		2	0								
1980	14 Apr	14	4	2	803	0.8	399	0.4	1,202	1.2	15.0
1981	14 Apr	18	18	7	7,810	7.8	953	1.0	8,762	8.8	109.5
1982	29 Apr-10 May	25	20	18	22,754	22.8	408	0.4	23,163	23.2	289.5
1983	30 Apr- 4 May	47	38	26	16,041	16.0	9,117	9.1	25,158	25.2	314.5
1984	24 Apr- 8 May	65	45	37	5,824	5.8	17,042	17.0	22,866	22.9	285.8
1985	25 Apr- 7 May	81	59	50	10,976	11.0	25,461	25.5	36,437	36.4	455.5
1986	21 Apr-28 Apr	104	82	81	0	0.0	65,499	65.5	65,499	65.5	818.7
1987	10 Apr-21 Apr	111	111	108	0	0.0	55,520	55.5	55,520	55.5	694.0
1988	12 Apr-23 Apr	122	122	119	0	0.0	112,854	112.9	112,854	112.9	1,410.7
1989[g]	Season Closed										
n		10	10	9	9	9	9	9	9	9	9
Mean		58.9	49.9	49.8	7,134	7.1	31,917	31.9	39,051	39.1	488.1
SE		13.9	13.6	14.4	2,721	2.7	12,890	12.9	11,476	11.5	143.4
Min		2	0	2	0	0.0	399	0.4	1,202	1.2	15.0
Max		122	122	119	22,754	22.8	112,854	112.9	112,854	112.9	1,410.7

[a] Dates the fishery was opened to seine herring for placement into pounds.
[b] Permits issued to applicants on register prior to the March 1 deadline.
[c] Number of individual pounds constructed by the April 1 deadline, and consequently the number of individuals receiving an equal allocation of the guideline harvest.
[d] Number of pounds that were successful in producing spawn-on-kelp product. Due to the group cooperation in this fishery production is frequently reported for a few individuals whose pounds did not produce spawn-on-kelp product.
[e] Production figures represent processed weights as reported on fish tickets.
[f] The herring used in the pound spawn-on-kelp fishery was estimated based on the assumption that it takes 12.5 tonnes of herring to produce 1.0 tonnes of spawn-on-kelp product.
[g] The herring pound spawn-on-kelp fishery in Prince William Sound was closed in 1989 due to the oil spill resulting from the grounding of the tanker M/V Exxon Valdez on 24 March 1989.

Table 5. Spawning biomass estimates and indices for herring in Prince William Sound, Alaska, 1975-89.

Year	Spawning Biomass Estimates		Kilometers of Spawning	Biomass of Herring per Kilometer (tonnes)		Biomass Ratio[a]
	Peak Aerial Survey (tonnes)	Spawn Deposition (tonnes)		Aerial Survey Estimate	Spawn Deposition Estimate	
1975	1,200.2					
1976	7,991.4					
1977	16,912.7					
1978	8,371.5		76.3	109.7		
1979	28,695.2		108.0	265.6		
1980	45,217.8		85.8	526.9		
1981	46,348.1		160.5	288.7		
1982	31,625.4		95.2	332.4		
1983	30,665.6	19,958.1	80.0	383.2	249.4	0.65
1984	41,417.6	72,311.8	105.9	391.0	682.6	1.75
1985	23,733.8		134.0	177.2		
1986	13,743.9		126.5	108.6		
1987	21,854.1		117.1	186.6		
1988	31,089.3	53,804.9	267.7	116.1	201.0	1.73
1989	35,956.3	52,235.5	163.3	220.2	320.0	1.45
n	15	3[b]	12	12	3[b]	3[b]
Mean	25,654.9	59,450.7	126.7	258.9	401.2	1.64
SE	3,592.5	6,446.5	15.2	37.9	144.8	0.10
Min	1,200.2	52,235.5	76.3	108.6	201.0	1.45
Max	46,348.1	72,311.8	267.7	526.9	682.6	1.75

[a] Biomass ratio was the spawn deposition spawning biomass estimate divided by the peak aerial survey spawning biomass estimate.

[b] Estimate from 1983 spawn deposition survey was not included in summary estimates because the survey was a only a preliminary estimate.

Table 6. Season, location, effort, and harvest, by gear type, for the commercial herring fisheries in Prince William Sound, Alaska, 1989.

	Fishing Information				Harvest and Utilization (tonnes)	
Fishery	Area	Date	Duration	Effort	Spawn-on-Kelp	Herring
Sac Roe Purse Seine			Season Closed			0.0
Sac Roe Gill Net			Season Closed			0.0
Natural Spawn-on-Kelp[a]			Season Closed			0.0
Pound Spawn-on-Kelp[b]			Season Closed			0.0
1989 Estimated Harvest and Use[c]						0.0
1988 Food-and-bait Harvest		1 Nov- 7 Nov 1988		7 boats		1,111.3

[a] The harvest by divers of naturally occurring herring roe on native kelp species in Prince William Sound.
[b] The harvest of herring spawn-on-kelp produced in net pens or pounds.
[c] The 1989 commercial sac roe and spawn-on-kelp fisheries for herring were closed due to the oil spill resulting from the grounding of the tanker M/V Exxon Valdez on 24 March 1989.

Table 7. Estimates of the contributions of each age and year class to the herring harvested by the commercial purse seine food-and-bait fishery in Prince William Sound, Alaska, 1 November - 7 November 1988.

Year Class	Age Class	Number Sampled	Mean Weight (g)	Mean Standard Length (mm)	Harvest by Age Class			
					Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1987	1	0			0.0	0.0	0.0	0.0
1986	2	72	67	165	109.3	9.8	1,630.7	13.4
1985	3	114	83	177	214.3	19.3	2,582.0	21.3
1984	4	202	94	183	430.1	38.7	4,575.1	37.7
1983	5	74	100	187	167.6	15.1	1,676.0	13.8
1982	6	42	111	194	105.6	9.5	951.3	7.8
1981	7	19	116	197	49.9	4.5	430.3	3.5
1980	8	8	122	199	22.1	2.0	181.2	1.5
1979	9	5	110	194	12.5	1.1	113.2	0.9
1978	10	0			0.0	0.0	0.0	0.0
1977	11	0			0.0	0.0	0.0	0.0
1976	12	0			0.0	0.0	0.0	0.0
1975	13+	0			0.0	0.0	0.0	0.0
Total		536	91	181	1,111.3	100.0	12,139.9	100.0

Table 8. Age and sex composition, mean weight-at-age, and mean length-at-age of herring sampled from the harvest of the commercial purse seine food-and-bait fishery at Red Head, Prince William Sound, Alaska, 1 November 1988.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	n	%	n	%	n	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	37	6.9	35	6.5	72	13.4	68	15	66	12	67	14	166	11	164	9	165	10
3	63	11.8	51	9.5	114	21.3	84	13	82	13	83	13	176	7	177	8	177	8
4	97	18.1	105	19.6	202	37.7	95	14	93	15	94	15	182	8	184	8	183	8
5	42	7.8	32	6.0	74	13.8	102	19	97	16	100	18	187	9	187	10	187	9
6	26	4.9	16	3.0	42	7.8	111	21	111	14	111	18	194	11	195	6	194	9
7	14	2.6	5	0.9	19	3.5	109	19	134	25	116	23	181	9	206	9	197	10
8	4	0.7	4	0.7	8	1.5	120	10	124	3	122	8	196	7	202	1	199	6
9	3	0.6	2	0.4	5	0.9	110	16	110	7	110	13	196	12	193	7	194	10
10	0	0.0	0	0.0	0	0.0												
11	0	0.0	0	0.0	0	0.0												
12	0	0.0	0	0.0	0	0.0												
13	0	0.0	0	0.0	0	0.0												
Total	286	53.4	250	46.6	536	100.0	93	20	90	20	91	20	181	12	181	12	181	12
Unaged	35	54.7	29	45.3	64	100.0	86	18	86	21	86	19	179	11	180	13	179	12

Table 9. Spawning biomass estimates and indices, by area, for herring in Prince William Sound, Alaska, 1989.

Survey Area	Peak Aerial Survey Date[a]	Spawning Biomass Estimates		Observed Kilometers of Spawning	Biomass of Herring per Kilometer (tonnes)		Biomass Ratio[c]
		Peak Aerial Survey (tonnes)	Spawn Deposition (tonnes)[b]		Aerial Survey Estimate	Spawn Deposition Estimate	
Southeast Shore Area		0.0	40.6	5.6	0.0	7.2	
Northeast Shore Area		3,946.3	7,148.4	34.8	113.5	205.6	1.81
North Shore Area	12 April 1989	2,721.6	18,161.8	49.4	55.1	367.4	6.67
Naked Island Area		4,340.9	10,145.0	22.1	196.8	459.9	2.34
Montague Island Area		24,947.6	16,739.7	46.5	536.2	359.8	0.67
All Areas Total	12 April 1989	35,956.3	52,235.4	158.4	227.0	329.7	1.45

[a] Date(s) the peak biomass observations were made.
[b] Herring spawning biomass estimates were made based on spawn deposition surveys.
[c] Biomass ratio was the spawn deposition spawning biomass estimate divided by the peak aerial survey spawning biomass estimate.

Table 10. Estimated spawning biomass of herring in tonnes, by area and date, based on aerial surveys in Prince William Sound, Alaska, during 1989. Aerial surveys were not flown every day in all the areas because of limited flying time.

	Southeast-Shore Area			Northeast-Shore Area				North-Shore Area		Naked Island Area		Montague Is. Area		
Date	Simpson Sheep & Islands	Hinchin-Brook Island	Port Gravina	Port Fidalgo	Tatitlek Area	Bligh Island	Valdez Arm & Port	Freemantle Granite Pt.	Granite Pt. Esther Pass.	Naked Island	Knight Island	Montague Island	Daily Survey Total	Date
03/30	0.0	NS	0.0	0.0	136.1	0.0	0.0	NS	NS	0.0	NS	NS	136.1	03/30
03/31	0.0	NS	0.0	9.1	181.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	190.5	03/31
04/01	0.0	NS	NS	90.7	344.7	NS	0.0	0.0	952.5	NS	0.0	NS	1,388.0	04/01
04/02	0.0	NS	0.0	0.0	54.4	NS	18.1	0.0	1,324.5	226.8	0.0	0.0	1,623.9	04/02
04/03	0.0	NS	0.0	9.1	335.7	NS	49.9	0.0	1,183.9	145.1	0.0	NS	1,723.7	04/03
04/04	0.0	NS	0.0	362.9	0.0	NS	0.0	0.0	1,868.8	117.9	72.6	0.0	2,422.2	04/04
04/05	0.0	NS	63.5*	1,632.9	526.2	NS	0.0	27.2	4,227.5	499.0	0.0	0.0	6,976.3	04/05
04/06	0.0	NS	0.0	272.2	898.1*	0.0	281.2	290.3	7,139.6	961.6	0.0	0.0	9,843.0	04/06
04/07	9.1*	0.0	0.0	753.0	571.5	NS	412.8	3,728.5*	8,781.6*	1,369.9	NS	NS	15,626.3	04/07
04/08	0.0	NS	0.0	81.6	435.4	18.1	4,998.6*	1,732.7	6,749.5	1,905.1	81.6	0.0	16,002.8	04/08
04/09	0.0	0.0	NS	176.9	281.2	NS	684.9	1,102.2	7,538.7	1,474.2	NS	0.0	11,258.2	04/09
04/10	No survey due to poor weather													04/10
04/11	NS	NS	NS	970.7	308.4	235.9*	2,630.8	99.8	1,778.1	2,785.1	0.0	0.0	8,808.8	04/11
04/12	0.0	0.0	NS	1,723.7*	371.9	0.0	1,850.7	843.7	1,877.9	4,340.9*	NS	24,947.6*	35,956.3	04/12
04/13	NS	NS	NS	208.7	90.7	163.3	353.8	489.9	263.1	880.0	72.6	18,651.7	21,173.7	04/13
04/14	0.0	NS	NS	163.3	9.1	113.4	267.6	140.6	95.3	571.5	72.6	13,430.9	14,864.2	04/14
04/15	NS	NS	18.1	36.3	0.0	0.0	9.1	0.0	18.1	462.7	190.5*	12,183.5	12,918.3	04/15
04/16	No survey due to poor weather													04/16
04/17	0.0	0.0	18.1	13.6	0.0	0.0	29.9	0.0	27.2	0.0	136.1	1,696.4	1,921.4	04/17
04/18	NS	63.5*	0.0	0.0	0.0	0.0	9.1	0.0	0.0	190.5	154.2	4,799.0	5,216.3	04/18
04/19	0.0	0.0	NS	NS	NS	NS	NS	0.0	4.5	0.0	145.1	880.0	1,029.7	04/19
04/20	NS	NS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	127.0	0.0	127.0	04/20
04/21	NS	NS	NS	NS	NS	NS	NS	0.0	NS	0.0	117.9	0.0	117.9	04/21
04/22	NS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.4	0.0	54.4	04/22
04/23	No survey due to poor weather													04/23
04/24	No survey due to poor weather													04/24
04/25	No survey due to poor weather													04/25
04/26	No survey due to poor weather													04/26
04/27	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0	0.0	0.0	0.0	04/27
Number of Surveys	15	7	14	20	20	13	20	21	20	22	19	19	23	
Peak Biomass Estimates by Area	9.1	63.5	63.5	1,723.7	898.1	235.9	4,998.6	3,728.5	8,781.6	4,340.9	190.5	24,947.6	49,981.4	
% of Total	0.0%	0.1%	0.1%	3.4%	1.8%	0.5%	10.0%	7.5%	17.6%	8.7%	0.4%	49.9%	100.0%	
by Major Areas			136.1				7,856.2		12,510.1		4,531.4	24,947.6	49,981.4	
% of Total			0.3%				15.7%		25.0%		9.1%	49.9%	100.0%	

NS = "No survey".
* = Aerial survey estimates that were included in the peak biomass estimates.

Table 11. Estimates of the contributions of each age and year class to the estimated spawning biomass (from spawn deposition surveys) of herring in the southeast-shore area, Prince William Sound Alaska, 1989.

Year Class	Age Class	Number Sampled	Mean Weight (g)	Mean Standard Length (mm)	Biomass by Age Class			
					Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1988	1	0			0.0	0.0	0.0	0.0
1987	2	0			0.0	0.0	0.0	0.0
1986	3	4	72	177	0.2	0.4	2.4	0.8
1985	4	34	93	192	1.9	4.7	20.6	6.4
1984	5	348	120	209	25.3	62.2	210.8	65.9
1983	6	45	130	214	3.5	8.7	27.3	8.5
1982	7	28	148	222	2.5	6.2	17.0	5.3
1981	8	45	169	231	4.6	11.3	27.3	8.5
1980	9	17	171	233	1.8	4.3	10.3	3.2
1979	10	4	201	246	0.5	1.2	2.4	0.8
1978	11	1	183	243	0.1	0.3	0.6	0.2
1977	12	2	192	242	0.2	0.6	1.2	0.4
1976	13+	0			0.0	0.0	0.0	0.0
Total		528	122	212	40.6	100.0	319.8	100.0

Table 12. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Two Moon Bay, southeast-shore area, Prince William Sound, Alaska, 5 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	2	0.4	2	0.4	4	0.8	67	7	78	13	72	11	171	1	182	3	177	7
4	17	3.2	17	3.2	34	6.4	89	25	97	13	93	20	189	16	195	9	192	13
5	144	27.4	204	38.8	348	65.9	115	16	125	16	120	17	206	10	210	8	209	9
6	21	4.0	23	4.4	45	8.5	121	27	139	24	130	27	211	17	216	12	214	15
7	18	3.4	10	1.9	28	5.3	140	21	163	26	148	25	219	11	228	10	222	11
8	22	4.2	22	4.2	45	8.5	163	22	176	20	169	22	230	9	231	8	231	8
9	6	1.1	11	2.1	17	3.2	179	19	167	18	171	19	239	9	230	10	233	11
10	0	0.0	4	0.8	4	0.8			201	22	201	22			246	8	246	8
11	1	0.2	0	0.0	1	0.2	183				183		243				243	
12	2	0.4	0	0.0	2	0.4	192	10			192	10	242	18			242	18
13	0	0.0	0	0.0	0	0.0												
Total	233	44.3	293	55.7	528	100.0	122	28	132	27	127	28	210	16	213	13	212	14
Unaged	15	53.6	13	46.4	28	100.0	134	44	121	28	128	37	213	23	207	17	210	20

Table 13. Estimates of the contributions of each age and year class to the estimated spawning biomass (from spawn deposition surveys) of herring in the northeast-shore area, Prince William Sound Alaska, 1989.

Year Class	Age Class	Number Sampled	Mean Weight (g)	Mean Standard Length (mm)	Biomass by Age Class			
					Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1988	1	0			0.0	0.0	0.0	0.0
1987	2	0			0.0	0.0	0.0	0.0
1986	3	4	64	176	38.1	0.5	595.6	0.9
1985	4	37	87	191	479.3	6.7	5,508.9	8.5
1984	5	346	110	205	5,666.8	79.3	51,516.0	79.9
1983	6	27	126	215	506.5	7.1	4,020.0	6.2
1982	7	5	145	222	107.9	1.5	744.5	1.2
1981	8	9	160	228	214.4	3.0	1,340.0	2.1
1980	9	3	175	232	78.2	1.1	446.7	0.7
1979	10	2	192	244	57.2	0.8	297.8	0.5
1978	11	0			0.0	0.0	0.0	0.0
1977	12	0			0.0	0.0	0.0	0.0
1976	13+	0			0.0	0.0	0.0	0.0
Total		433	111	205	7,148.4	100.0	64,469.4	100.0

Table 14. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Galena Bay and Johnson Cove, northeast-shore area, Prince William Sound, Alaska, 12 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	3	0.7	1	0.2	4	0.9	63	3	68		64	4	175	5	179		176	5
4	18	4.2	18	4.2	37	8.5	86	10	88	9	87	9	191	7	191	6	191	7
5	183	42.5	162	37.6	346	79.9	106	15	114	14	110	15	204	8	205	8	205	8
6	17	3.9	10	2.3	27	6.2	120	15	135	12	126	16	214	8	216	7	215	8
7	2	0.5	3	0.7	5	1.2	137	8	151	16	145	14	216	3	226	7	222	8
8	4	0.9	5	1.2	9	2.1	156	27	162	32	160	28	228	7	228	13	228	10
9	3	0.7	0	0.0	3	0.7	175	14			175	14	232	1			232	1
10	1	0.2	1	0.2	2	0.5	165		218		192	37	236		252		244	11
11	0	0.0	0	0.0	0	0.0												
12	0	0.0	0	0.0	0	0.0												
13	0	0.0	0	0.0	0	0.0												
Total	231	53.6	200	46.4	433	100.0	108	20	115	21	111	21	204	11	206	11	205	11
Unaged	15	41.7	21	58.3	38	100.0	110	21	112	20	110	20	207	12	204	11	205	11

Table 15. Estimates of the contributions of each age and year class to the estimated spawning biomass (from spawn deposition surveys) of herring in the north-shore area, Prince William Sound, Alaska, 1989.

Year Class	Age Class	Number Sampled	Mean Weight (g)	Mean Standard Length (mm)	Biomass by Age Class			
					Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1988	1	0			0.0	0.0	0.0	0.0
1987	2	0			0.0	0.0	0.0	0.0
1986	3	2	81	185	18.2	0.1	224.1	0.2
1985	4	58	95	193	617.5	3.4	6,499.9	4.7
1984	5	866	119	205	11,548.9	63.6	97,049.7	69.7
1983	6	86	140	217	1,349.3	7.4	9,637.7	6.9
1982	7	60	163	227	1,096.0	6.0	6,724.0	4.8
1981	8	91	175	232	1,784.7	9.8	10,198.1	7.3
1980	9	61	192	236	1,312.5	7.2	6,836.1	4.9
1979	10	10	213	248	238.7	1.3	1,120.7	0.8
1978	11	6	179	239	120.4	0.7	672.4	0.5
1977	12	3	225	251	75.6	0.4	336.2	0.2
1976	13+	0			0.0	0.0	0.0	0.0
Total		1,243	95	191	18,161.8	100.0	139,298.9	100.0

Table 16. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Unakwik Inlet and Olsen Cove, north-shore area, Prince William Sound, Alaska, 4 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	0	0.0	1	0.1	1	0.1			86		86				188		188	
4	16	2.0	19	2.3	35	4.3	89	12	100	15	95	14	192	7	197	8	195	8
5	248	30.4	278	34.1	528	64.6	116	16	123	17	120	17	206	9	208	10	207	10
6	22	2.7	37	4.5	59	7.2	140	16	141	21	140	19	219	11	216	10	217	10
7	29	3.6	15	1.8	44	5.4	157	19	165	22	159	20	227	7	227	7	227	7
8	28	3.4	48	5.9	76	9.3	171	26	178	22	176	24	231	9	234	9	233	9
9	30	3.7	28	3.4	58	7.1	184	26	194	16	189	22	236	10	239	6	237	8
10	4	0.5	4	0.5	8	1.0	197	16	215	12	206	16	245	6	248	5	247	5
11	4	0.5	2	0.2	6	0.7	189	42	179	25	185	35	240	9	237	13	239	10
12	0	0.0	2	0.2	2	0.2			212	6	212	6			248	1	248	1
13	0	0.0	0	0.0	0	0.0												
Total	381	46.7	434	53.3	817	100.0	130	32	137	32	134	32	213	15	215	15	214	15
Unaged	39	43.8	50	56.2	89	100.0	120	29	131	35	126	33	208	15	209	26	209	21

Table 17. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Cedar Bay, north-shore area, Prince William Sound, Alaska, 13 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	1	0.2	0	0.0	1	0.2	76				76		181				181	
4	14	3.3	9	2.1	23	5.4	88	9	88	12	88	10	190	6	187	10	189	8
5	193	45.7	141	33.4	338	79.3	108	15	122	16	114	17	202	8	206	8	203	8
6	14	3.3	13	3.1	27	6.3	130	24	145	16	137	22	215	8	217	7	216	8
7	9	2.1	7	1.7	16	3.8	154	14	163	9	158	13	226	9	227	6	227	7
8	8	1.9	7	1.7	15	3.5	154	21	167	16	160	19	226	12	230	10	228	11
9	1	0.2	2	0.5	3	0.7	161		149	49	153	36	228		223	21	225	15
10	1	0.2	1	0.2	2	0.5	209		202		206	5	253		247		250	4
11	0	0.0	0	0.0	0	0.0												
12	0	0.0	1	0.2	1	0.2			252		252				258		258	
13	0	0.0	0	0.0	0	0.0												
Total	241	57.1	181	42.9	426	100.0	112	22	127	24	118	24	204	12	208	12	206	12
Unaged	14	58.3	10	41.7	24	100.0	118	29	118	18	118	25	206	15	205	7	206	12

Table 18. Estimates of the contributions of each age and year class to the estimated spawning biomass (from spawn deposition surveys) of herring in the Naked Island area, Prince William Sound, Alaska, 1989.

Year Class	Age Class	Number Sampled	Mean Weight (g)	Mean Standard Length (mm)	Biomass by Age Class			
					Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1988	1	0			0.0	0.0	0.0	0.0
1987	2	0			0.0	0.0	0.0	0.0
1986	3	0			0.0	0.0	0.0	0.0
1985	4	30	92	193	568.3	5.6	6,177.0	7.2
1984	5	335	113	206	7,794.4	76.8	68,977.0	80.0
1983	6	18	132	217	489.2	4.8	3,706.2	4.3
1982	7	13	156	228	417.6	4.1	2,676.7	3.1
1981	8	13	175	235	468.4	4.6	2,676.7	3.1
1980	9	5	190	235	195.6	1.9	1,029.5	1.2
1979	10	2	176	237	72.5	0.7	411.8	0.5
1978	11	1	229	254	47.2	0.5	205.9	0.2
1977	12	2	223	257	91.8	0.9	411.8	0.5
1976	13+	0			0.0	0.0	0.0	0.0
Total		419	117	208	10,145.0	100.0	86,272.7	100.0

Table 19. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Outside Bay, Naked Island area, Prince William Sound, Alaska, 11 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	0	0.0	0	0.0	0	0.0												
4	16	3.8	14	3.3	30	7.2	89	13	97	17	92	15	192	8	195	12	193	10
5	172	41.1	162	38.8	335	80.0	109	15	117	15	113	16	205	8	206	8	206	8
6	13	3.1	5	1.2	18	4.3	130	11	137	31	132	18	217	7	216	16	217	10
7	6	1.4	7	1.7	13	3.1	151	14	159	21	156	18	226	8	230	9	228	9
8	10	2.4	3	0.7	13	3.1	168	26	198	6	175	26	232	11	244	7	235	11
9	3	0.7	2	0.5	5	1.2	187	15	195	52	190	29	232	3	239	21	235	11
10	1	0.2	1	0.2	2	0.5	159		193		176	24	226		248		237	16
11	1	0.2	0	0.0	1	0.2	229				229		254				254	
12	0	0.0	2	0.5	2	0.5			223	18	223	18			257	6	257	6
13	0	0.0	0	0.0	0	0.0												
Total	222	53.1	196	46.9	419	100.0	114	25	121	26	117	26	207	12	208	13	208	13
Unaged	12	38.7	19	61.3	31	100.0	108	22	127	29	120	27	206	12	210	12	209	12

Table 20. Estimates of the contributions of each age and year class to the estimated spawning biomass (from spawn deposition surveys) of herring in the Montague Island area, Prince William Sound Alaska, 1989.

Year Class	Age Class	Number Sampled	Mean Weight (g)	Mean Standard Length (mm)	Biomass by Age Class			
					Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1988	1	0			0.0	0.0	0.0	0.0
1987	2	0			0.0	0.0	0.0	0.0
1986	3	11	72	178	96.4	0.6	1,338.3	0.8
1985	4	112	83	186	1,131.0	6.8	13,626.7	8.6
1984	5	1,103	106	200	14,225.1	85.0	134,198.7	84.7
1983	6	36	119	208	521.2	3.1	4,380.0	2.8
1982	7	11	145	223	194.1	1.2	1,338.3	0.8
1981	8	16	148	222	288.1	1.7	1,946.7	1.2
1980	9	10	156	234	189.8	1.1	1,216.7	0.8
1979	10	2	201	245	48.9	0.3	243.3	0.2
1978	11	2	186	240	45.3	0.3	243.3	0.2
1977	12	0			0.0	0.0	0.0	0.0
1976	13+	0			0.0	0.0	0.0	0.0
Total		1,303	106	200	16,739.8	100.0	158,532.1	100.0

Table 21. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Rocky Bay, Montague Island area, Prince William Sound, Alaska, 13 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	2	0.5	2	0.5	4	0.9	84	4	84	21	84	12	192	4	187	13	189	8
4	19	4.3	12	2.7	31	7.0	83	16	91	16	86	16	190	10	195	13	192	11
5	205	46.4	174	39.4	380	85.8	105	15	113	18	109	17	204	9	205	11	204	10
6	11	2.5	7	1.6	18	4.1	114	18	131	20	121	20	210	10	214	10	212	10
7	4	0.9	1	0.2	5	1.1	140	18	145		141	16	225	11	237		227	11
8	3	0.7	1	0.2	4	0.9	126	8	194		143	35	219	10	241		224	14
9	0	0.0	0	0.0	0	0.0												
10	0	0.0	0	0.0	0	0.0												
11	1	0.2	0	0.0	1	0.2	186				186		244				244	
12	0	0.0	0	0.0	0	0.0												
13	0	0.0	0	0.0	0	0.0												
Total	245	55.4	197	44.6	443	100.0	105	18	113	20	108	19	204	11	205	12	204	11
Unaged	1	14.3	6	85.7	7	100.0	125		106	24	109	23	216		202	12	204	12

Table 22. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Zaikof Bay, Montague Island area, Prince William Sound, Alaska, 17 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	1	0.2	0	0.0	1	0.2	76				76		183				183	
4	23	5.3	9	2.1	32	7.3	80	8	89	8	82	9	186	6	189	4	187	6
5	242	56.1	138	32.0	385	88.1	101	16	111	18	105	17	200	8	203	9	201	9
6	6	1.4	3	0.7	9	2.1	104	14	111	10	106	13	199	11	203	3	201	9
7	2	0.5	2	0.5	4	0.9	158	69	136	6	147	42	224	23	213	1	219	15
8	1	0.2	2	0.5	4	0.9	109		137	2	138	25	207		217	8	220	14
9	1	0.2	1	0.2	2	0.5	178		177		178	1	238		237		238	1
10	0	0.0	0	0.0	0	0.0												
11	0	0.0	0	0.0	0	0.0												
12	0	0.0	0	0.0	0	0.0												
13	0	0.0	0	0.0	0	0.0												
Total	276	64.0	155	36.0	437	100.0	100	18	111	19	104	19	199	10	202	10	201	10
Unaged	10	76.9	3	23.1	13	100.0	106	27	136	22	113	28	204	16	214	5	206	15

Table 23. Age and sex composition, mean weight at age, and mean length at age of herring sampled from test fish purse seine catches at Stockdale Harbor, Montague Island area, Prince William Sound, Alaska, 18 April 1989.

	Age and Sex Composition						Weight (g)						Standard Length (mm)					
	Male		Female		Combined		Male		Female		Combined		Male		Female		Combined	
Age	*N*	%	*N*	%	*N*	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	0	0.0	0	0.0	0	0.0												
3	3	0.7	3	0.7	6	1.4	58	6	70	7	64	9	167	3	171	4	169	4
4	34	8.0	15	3.5	49	11.6	81	12	83	9	82	11	182	9	181	6	182	8
5	176	41.6	162	38.3	338	79.9	101	15	110	17	105	16	194	11	197	9	195	10
6	5	1.2	4	0.9	9	2.1	109	22	152	17	128	29	200	12	214	9	206	12
7	1	0.2	1	0.2	2	0.5	162		139		151	16	226		213		220	9
8	6	1.4	2	0.5	8	1.9	146	20	186	47	156	31	217	10	234	5	221	11
9	5	1.2	3	0.7	8	1.9	158	14	141	29	151	20	228	8	214	13	223	11
10	0	0.0	2	0.5	2	0.5			201	19	201	19			245	10	245	10
11	1	0.2	0	0.0	1	0.2	185				185		235				235	
12	0	0.0	0	0.0	0	0.0												
13	0	0.0	0	0.0	0	0.0												
Total	231	54.6	192	45.4	423	100.0	101	21	110	24	105	23	194	14	197	13	195	13
Unaged	11	40.7	16	59.3	27	100.0	98	14	110	22	105	20	195	9	197	14	196	12

Table 24. Estimates of the contributions of each age and year class to the estimated spawning biomass (from spawn deposition surveys) of herring in Prince William Sound, Alaska, 1989.

Year Class	Age Class	Mean Weight (g)	Biomass by Age Class			
			Weight (tonnes)	Percent by Weight	Number of Fish (x 1,000)	Percent by Number
1988	1		0.0	0.0	0.0	0.0
1987	2		0.0	0.0	0.0	0.0
1986	3	71	152.8	0.3	2,160.5	0.5
1985	4	88	2,798.0	5.4	31,833.1	7.1
1984	5	112	39,260.4	75.2	351,952.2	78.4
1983	6	132	2,869.8	5.5	21,771.3	4.8
1982	7	158	1,818.1	3.5	11,500.5	2.6
1981	8	171	2,760.2	5.3	16,188.7	3.6
1980	9	186	1,777.9	3.4	9,539.2	2.1
1979	10	201	417.8	0.8	2,076.0	0.5
1978	11	190	212.9	0.4	1,122.2	0.3
1977	12	224	167.7	0.3	749.2	0.2
1976	13+		0.0	0.0	0.0	0.0
Total		116	52,235.5	100.0	448,892.9	100.0

Table 25. Estimates of the exploitation rate, by weight, of each age and year class and a summary of the contributions of each age class and year class to the harvest, escapement biomass, and total spawning biomass of herring in Prince William Sound, Alaska, 1989.

Year Class	Age Class	1988 Food-and-Bait Harvest (tonnes)[a]	1989 Herring Sac Roe Harvest and Spawn-on-Kelp Use (tonnes)				1989 Harvest and Use	1989 Escapement Biomass (tonnes)[b]	1989 Spawning Biomass (tonnes)[b]	1988-89 Total Biomass (tonnes)[c]	1988-89 Combined Harvest (tonnes)[d]	Estimated Exploitation Rate (by weight)[e]
			Sac Roe Fisheries		Roe-on-kelp Fisheries							
			Purse Seine	Gill Net	Wild	Pound						
1987	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	3	109.2	0.0	0.0	0.0	0.0	0.0	152.8	152.8	262.0	109.2	41.7
1984	4	214.3	0.0	0.0	0.0	0.0	0.0	2,798.0	2,798.0	3,012.3	214.3	7.1
1983	5	430.1	0.0	0.0	0.0	0.0	0.0	39,260.4	39,260.4	39,690.5	430.1	1.1
1982	6	167.6	0.0	0.0	0.0	0.0	0.0	2,869.8	2,869.8	3,037.4	167.6	5.5
1981	7	105.6	0.0	0.0	0.0	0.0	0.0	1,818.1	1,818.1	1,923.7	105.6	5.5
1980	8	49.9	0.0	0.0	0.0	0.0	0.0	2,760.2	2,760.2	2,810.1	49.9	1.8
1979	9	22.1	0.0	0.0	0.0	0.0	0.0	1,777.9	1,777.9	1,800.0	22.1	1.2
1978	10	12.4	0.0	0.0	0.0	0.0	0.0	417.8	417.8	430.2	12.4	2.9
1977	11	0.0	0.0	0.0	0.0	0.0	0.0	212.9	212.9	212.9	0.0	0.0
1976	12	0.0	0.0	0.0	0.0	0.0	0.0	167.7	167.7	167.7	0.0	0.0
1975	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total		1,111.3	0.0	0.0	0.0	0.0	0.0	52,235.5	52,235.5	53,346.8	1,111.3	2.1

[a] The age class of a herring in the food-and-bait fishery corresponds to a one-year older age class in the spring spawning migration the following year. As an example, an age-2 fish in the 1988 food-and-bait fishery corresponds to an age-3 fish in the 1989 spring spawning migration.

[b] The 1989 escapement and total spawning biomass was the estimated spawning biomass from the spawn deposition survey.

[c] The 1988-89 total biomass was the sum of the harvest of the 1988 food-and-bait fishery and the 1989 total spawning biomass.

[d] The 1988-89 combined harvest and use was the harvest from the 1988 food-and-bait fishery.

[e] The estimated exploitation rate was the 1988-89 combined harvested herring and equivalent herring used divided by the 1988-89 total biomass.

Table 26. Estimates of the exploitation rate, by number, of each age and year class and the contributions of each age class and year class to the harvest, escapement biomass, and total spawning biomass of herring in Prince William Sound, Alaska, 1989.

Year Class	Age Class	1988 Food-and-Bait Harvest (x 1,000)[a]	1989 Herring Sac Roe Harvest and Spawn-on-Kelp Use (x 1,000)				1989 Harvest and Use	1989 Escapement Biomass (x 1,000)[b]	1989 Spawning Biomass (x 1,000)[b]	1988-89 Total Biomass (x 1,000)[c]	1988-89 Combined Harvest (x 1,000)[d]	Estimated Exploitation Rate (by number)[e]
			Sac Roe Fisheries		Spawn-on-kelp Fisheries							
			Purse Seine	Gill Net	Wild	Pound						
1988	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	2	1,630.7 (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,630.7	1,630.7	0.0
1986	3	2,582.0 (2)	0.0	0.0	0.0	0.0	0.0	2,160.5	2,160.5	4,742.5	2,582.0	54.4
1985	4	4,575.1 (3)	0.0	0.0	0.0	0.0	0.0	31,833.1	31,833.1	36,408.3	4,575.1	12.6
1984	5	1,676.0 (4)	0.0	0.0	0.0	0.0	0.0	351,952.2	351,952.2	353,628.2	1,676.0	0.5
1983	6	951.3 (5)	0.0	0.0	0.0	0.0	0.0	21,771.3	21,771.3	22,722.5	951.3	4.2
1982	7	430.3 (6)	0.0	0.0	0.0	0.0	0.0	11,500.5	11,500.5	11,930.8	430.3	3.6
1981	8	181.2 (7)	0.0	0.0	0.0	0.0	0.0	16,188.7	16,188.7	16,369.9	181.2	1.1
1980	9	113.2 (8)	0.0	0.0	0.0	0.0	0.0	9,539.2	9,539.2	9,652.5	113.2	1.2
1979	10	0.0 (9)	0.0	0.0	0.0	0.0	0.0	2,076.0	2,076.0	2,076.0	0.0	0.0
1978	11	0.0 (10)	0.0	0.0	0.0	0.0	0.0	1,122.2	1,122.2	1,122.2	0.0	0.0
1977	12	0.0 (11)	0.0	0.0	0.0	0.0	0.0	749.2	749.2	749.2	0.0	0.0
1976	13	0.0 (12)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total		12,139.9	0.0	0.0	0.0	0.0	0.0	448,892.9	448,892.9	461,032.8	12,139.9	2.6

[a] The age class of a herring in the food-and-bait fishery corresponds to a one-year older age class in the spring spawning migration. As an example, an age-2 fish in the 1988 food-and-bait fishery corresponds to an age-3 fish in the 1989 spring spawning migration.

[b] The 1989 escapement and total spawning biomass was the estimated spawning biomass from the spawn deposition survey.

[c] The 1988-89 total biomass was the sum of the harvest of the 1988 food-and-bait fishery and the 1989 total spawning biomass.

[d] The 1988-89 combined harvest and use was the harvest from the 1988 food-and-bait fishery.

[e] The estimated exploitation rate was the 1988-89 combined harvested herring and equivalent herring divided by the 1988-89 total biomass.

FIGURES

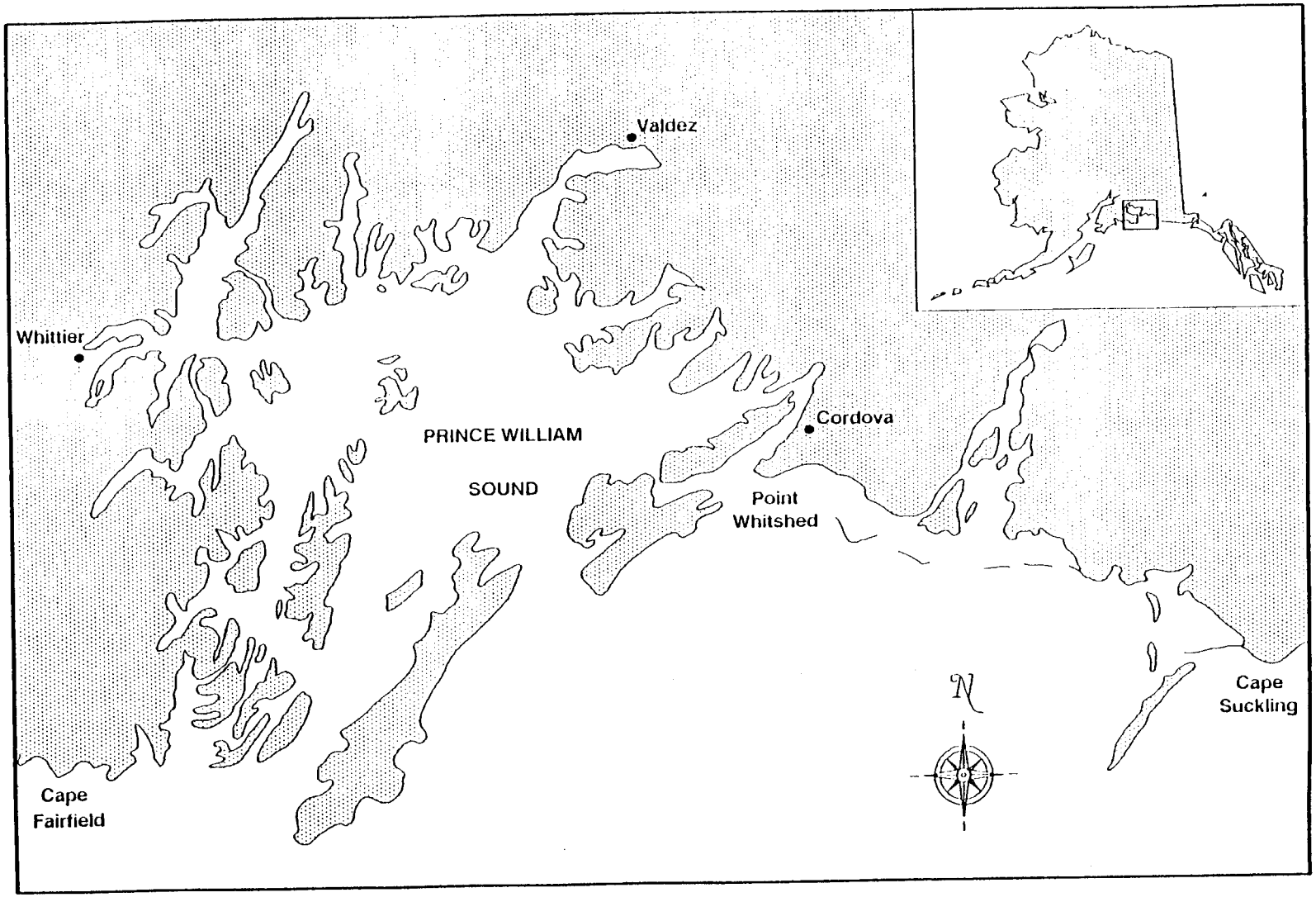

Figure 1. Map of Prince William Sound, Alaska.

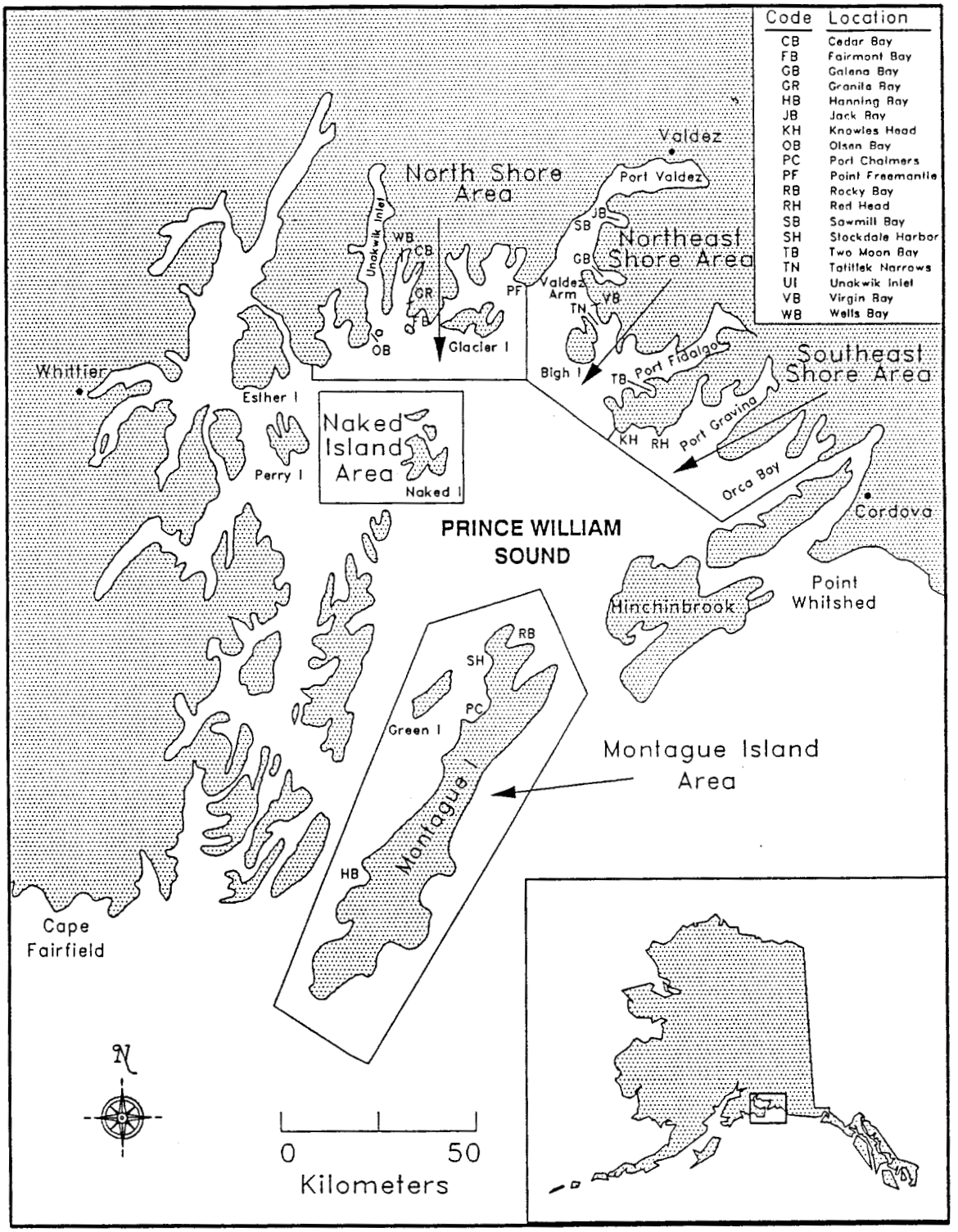

Figure 2. Location of the major spawning areas for herring in Prince William Sound, Alaska, 1989.